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Site-wide occupancy assessment using camera traps for seven mammalian species at Los Alamos National Laboratory

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Introduction

Los Alamos National Laboratory (LANL or Laboratory) is committed to solving national security challenges through scientific excellence and has been serving the nation and northern New Mexico for over 70 years. Being located on the Pajarito Plateau in the eastern flanks of the Jemez Mountains, the Laboratory is surrounded by a rich diversity of plants and animals. It is common to see many different species of wildlife on Laboratory property; however, sometimes interactions with wildlife can be negative. Vehicle accidents with wildlife have become a common occurrence. With the current and ongoing expansion of the Laboratory on the Pajarito Plateau, it has the potential to further impact wildlife movement including large game species. Local agencies and tribal Pueblos rely on large game species and do not want these species to be restricted from moving across property boundaries. Temporal and spatial aspects of where wildlife occur on the site is a phenomena that is either not well understood in uncommon species or needs periodic reevaluation for common species.

Estimating the distribution of multiple species across the landscape provides wildlife biologists with crucial information for monitoring and conserving animal populations in a particular area (Noon et al. 2012). Utilizing motion activated wildlife cameras, also known as camera traps, to monitor wildlife populations has become an essential tool for biologists (Locke et al. 2012). Camera traps are non-invasive and cost-effective and can document multiple elusive or uncommon wildlife species, such as carnivores, simultaneously (Kays and Slauson 2008, Steenweg et al. 2019).

Occupancy modeling provides a flexible framework for the analysis of the distribution for multiple wildlife species. It explicitly recognizes whether a species is spatially common or rare (occupancy = ψ) and if that species is easy or hard to detect (detection probability = p). Multi-species and multi-season occupancy models can detect trends in species occupancy because individual species may vary in seasonal movements, detection probability, and transition rates between habitats (Steenweg et al. 2019).

In this study, we assessed the site as a whole to ascertain when and where medium and large mammal species are present. Understanding wildlife patterns at the Laboratory will better inform future management decisions regarding land use and development strategies. We placed motion activated wildlife cameras in a random systematic sampling design and used these data to create occupancy models.

We tested for differences in single-species occupancy and detection probability by season of mammal species captured on 20 camera traps placed across the Laboratory in a 40 mi^2 (103 km^2) area. We focus the interpretation of our findings on seven mammal species found during this study. They are Rocky Mountain elk (*Cervus canadensis nelsoni*; hereafter "elk"), mule deer (*Odocoileus hemionus*; hereafter "deer"), mountain lion (*Puma concolor*; hereafter "lion"), American black bear (*Ursus americanus*; hereafter "bear"), coyote (*Canis latrans*), bobcat (*Lynx rufus*), and gray fox (*Urocyon cinereoargenteus*; hereafter "fox").

Methods

Camera Site Location and Field Methods

To acquire an accurate and unbiased dataset from across the Laboratory, we placed cameras randomly using a systematic 0.9 mi^2 (2.25 km^2) grid cell design. At the center of each equidistant grid cell was a potential camera trap location. We omitted some grid cells from the study due to pre-defined constraints. We chose constraints in order to eliminate potential bias in the data. We excluded grid cells that showed >50% developed land from land cover data (Hansen et al. 2018). Other constraints that eliminated or modified cells were locations where the center landed on a road that adjoined two developed areas, or on a steep inaccessible cliff face. This approach yielded 36 potential cells for cameras across the property.

We entered all of the potential cell locations into an Excel$^©$ spreadsheet and assigned random numbers using the randomization function which randomizes a list. We randomized the locations ten times and sorted from smallest to largest. We designated the first 20 in this sorting as primary locations with the following five being designated as alternate locations, in case there were any problems with a primary location.

After we selected locations using the methods described above, we generated a map and sent it to management and security personnel (Figure 1). Approved security controls included mounting cameras where there would be no chance to detect buildings, traffic, or personnel. In addition, we physically secured all cameras with an interlocking exterior steel case, cable lock, and a padlock. We placed a laminated card with the researcher's contact information on top of the camera in the event that the camera was discovered by people not privy to the study. During the setup period, we instituted standards to avoid some common pitfalls of camera trap studies (Burton et al. 2015). Those were:

- All cameras were attached to trees (living or dead). Limbs and vegetation blocking the aperture were trimmed as needed.

- All cameras were mounted due North (if possible) to avoid 'wash out" from sunrise or sunset.

- All cameras were mounted using 3 in (7.6 cm) wood screws to keep angles and detection zones consistent.

- All cameras were set approximately 3 ft (0.91 m) off the ground.

- All cameras were set in areas with appropriate fields of detection (i.e. not in an oak thicket but rather an opening between two thickets).

- When possible, cameras were set along game trails and natural travel corridors. Pedestrian running/hiking trails were avoided.
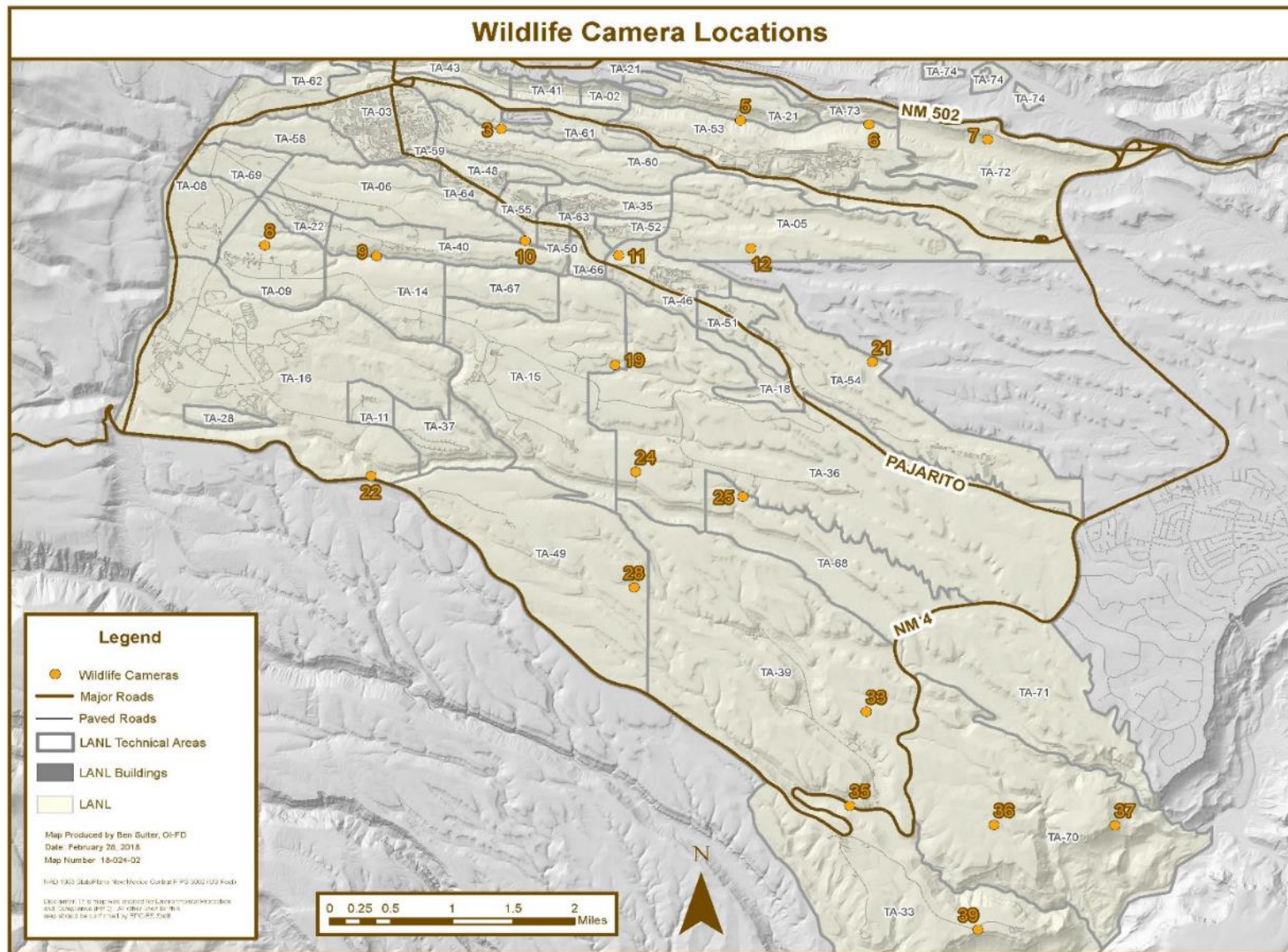
Figure 1. Final locations of cameras deployed across LANL.

We used Reconyx© HyperFire Professional IR PC800 model cameras for this study. Camera deployment began on 20 November 2017 with all 20 cameras deployed by 1 February 2018. Cameras operated for at least a year. Elevations for deployment sites ranged from 6,404 ft (1,952 m) to 7,202 ft (2,195 m). We checked all cameras several times throughout their deployment to ensure that batteries were functional, to swap memory cards, and to confirm correct aspect/image capture. The study period was one full year (February 2018 to February 2019); all cameras operated at the same time. Beginning on 4 February 2019 until 8 March 2019, we removed the deployed cameras. We excluded excess data retrieved from cameras deployed for more than a year in this analysis.

We copied all the memory cards' images and stored them on a secure computer. A researcher reviewed all images and deleted any images that did not contain wildlife. Once this process was complete, we tabulated and recorded data from the images into a spreadsheet. Data records included species type, number of individuals, sex, whether or not young were present, and the count of total images taken during a detection. A detection was defined as any image(s) with one or more animals present within a ten minute time frame. For example if an image contained two elk it would be documented as one detection. Exceptions applied to the ten minute time frame such as a group of elk sleeping in front of the camera. We binned all species detections into week-long intervals throughout the year-long study period. We compiled data into a format for statistical analysis using the program R (R Core Team 2019).

Statistical Methods
We used a dynamic occupancy analysis model (MacKenzie et al. 2003) to estimate species-specific occupancy and detection probability by season. Occupancy (ψ) is the probability that a species is present at a sampled location, and detection probability (p) is the probability that a species will be detected at a sampling location, conditional on the presence of that animal at that site. The dynamic occupancy model allows for multi-season and between season occurrence estimates to be incorporated into the analysis. The model provides seasonal occupancy probabilities that account for seasonal variation in the probability of detection rates, as well as transition rates between seasons. In other words, our multi-season occupancy model assumed the presence or absence of a particular species at a location in a given season, and it was independent of whether the species were present at that location in the previous season. This approach allowed us to determine if season had an effect on occupancy, movement between sampling locations, and detection probability. For each species, we tested four competing models: (1) differences in movement between sampling locations by season and differences in detection probability by season; (2) constant movement between sampling locations by season but differences in seasonal detection probabilities; (3) differences in movement between sampling locations by season but constant detection probability by season; (4) constant detection probability by season and constant movement between sampling locations by season (Table 1). We used the package "unmarked" (Fiske and Chandler 2011) from the R statistical software version 3.5.3 for all data analyses (R Core Team 2019).

Results

During one year of monitoring, the cameras captured over 20,000 images and of those 5,828 images with wildlife were present. The raw image data was further condensed by our definition of a detection to yield the numbers for analysis below. We analyzed photographic data for seven mammal species: elk (n=591), deer (n=672), lion (n=10), bear (n=32), coyote (n=56), bobcat (n=27), and fox (n=8). For each species, we tested four initial model sets (Table 1) and reported the lowest Akaike information criterion (AIC) models for each species in Table 2. The top model for elk, deer, lion, and fox showed constant detection probability and movement between sampling locations by season (Table 1, model #4). The top model for bear, coyote, and bobcat showed differences in seasonal detection probabilities, but constant movement between sampling locations by season (Table 1, model #2). Occupancy (ψ) and detection probabilities (p) varied across species and seasons in our study area. Both ψ and p were highest for common species and lowest for uncommon species suggesting that species which were more numerous on the landscape had higher detection probabilities and occupancy.

Additional data are available in the appendices: Appendix A – Maps of detections by site, season, and species; Appendix B – Summary tables of all data; Appendix C – Representative pictures of wildlife; and Appendix D – Data on each of the cameras.

Table 1. The four candidate models tested independently for elk, deer, lion, bear, coyote, bobcat, and fox.

Model #	Models Tested for Each Species	Description
1	$\psi = \sim1, \sim$season-1, $\sim$season-1, $\sim$season-1	Differences in movement between sampling locations by season, and differences in detection probability by season
2	$\psi = \sim1, \sim1, \sim1, \sim$season-1	Constant movement between sampling locations by season, but differences in seasonal detection probabilities
3	$\psi = \sim1, \sim$season-1, $\sim$season-1, ~1	Differences in movement between sampling locations by season, but constant detection probability by season
4	$\psi = \sim1, \sim1, \sim1, \sim1$	Constant detection probability by season and constant movement between sampling locations by season

Table 2. Model selection results for each species with Akaike's Information Criterion (AIC), difference in AIC between each model compared to the model with the lowest AIC (ΔAIC) and relative Akaike weights (w_i); the top model for each species is indicated by bold in w_i column.

Species	Models	AIC	ΔAIC	w_i
Elk	Model 1. ψ = ~1, ~season-1, ~season-1, ~season-1	765.83	6.80	0.02
	Model 2. ψ = ~1, ~1, ~1, ~season-1	763.30	4.27	0.08
	Model 3. ψ = ~1, ~season-1, ~season-1, ~1	761.50	2.47	0.20
	Model 4. ψ = ~1, ~1, ~1, ~1	**759.03**	**0.00**	**0.69**
Deer	Model 1. ψ = ~1, ~season-1, ~season-1, ~season-1	1080.22	6.20	0.03
	Model 2. ψ = ~1, ~1, ~1, ~season-1	1077.83	3.81	0.10
	Model 3. ψ = ~1, ~season-1, ~season-1, ~1	1076.44	2.42	0.20
	Model 4. ψ = ~1, ~1, ~1, ~1	**1074.02**	**0.00**	**0.67**
Lion	Model 1. ψ = ~1, ~season-1, ~season-1, ~season-1	120.43	10.64	0.00
	Model 2. ψ = ~1, ~1, ~1, ~season-1	114.98	5.18	0.06
	Model 3. ψ = ~1, ~season-1, ~season-1, ~1	112.73	2.94	0.18
	Model 4. ψ = ~1, ~1, ~1, ~1	**109.79**	**0.00**	**0.76**
Bear	Model 1. ψ = ~1, ~season-1, ~season-1, ~season-1	195.91	7.55	0.02
	Model 2. ψ = ~1, ~1, ~1, ~season-1	**188.36**	**0.00**	**0.92**
	Model 3. ψ = ~1, ~season-1, ~season-1, ~1	196.37	8.01	0.02
	Model 4. ψ = ~1, ~1, ~1, ~1	194.36	6.00	0.05
Coyote	Model 1. ψ = ~1, ~season-1, ~season-1, ~season-1	301.08	4.83	0.08
	Model 2. ψ = ~1, ~1, ~1, ~season-1	**296.24**	**0.00**	**0.84**
	Model 3. ψ = ~1, ~season-1, ~season-1, ~1	304.59	8.35	0.01
	Model 4. ψ = ~1, ~1, ~1, ~1	301.06	4.82	0.08
Bobcat	Model 1. ψ = ~1, ~season-1, ~season-1, ~season-1	226.09	4.64	0.05
	Model 2. ψ = ~1, ~1, ~1, ~season-1	**221.45**	**0.00**	**0.51**
	Model 3. ψ = ~1, ~season-1, ~season-1, ~1	229.24	7.79	0.01
	Model 4. ψ = ~1, ~1, ~1, ~1	221.77	0.32	0.43
Fox	Model 1. ψ = ~1, ~season-1, ~season-1, ~season-1	108.79	9.89	0.00
	Model 2. ψ = ~1, ~1, ~1, ~season-1	103.50	4.60	0.06
	Model 3. ψ = ~1, ~season-1, ~season-1, ~1	100.54	1.63	0.29
	Model 4. ψ = ~1, ~1, ~1, ~1	**98.90**	**0.00**	**0.65**

Probability of occupancy

Occupancy estimates and standard errors across all four season are displayed in Table 3. Occupancy ranged from 0.81 (95% CI: 0.57–0.93) for deer to 0.36 (0.01–0.96) for lion (Table 4). In other words, there is an 81% probability that deer would occupy at least one of all possible locations sampled on LANL property anytime within a given year (Table 4; Figure 2), and a 36% probability that a lion would occupy one of all possible sampled locations anytime within a given year (Table 4; Figure 3). Similarly, the probability of occupancy for elk was 68%, fox 40%, bear 50%, coyote 16%, and bobcat 40% (Table 4). According to our results, the probability of occupancy by bears at a sampled location is highest in the spring, whereas the probability of occupancy by coyotes at a sampled location is highest in the winter (Table 4; Figure 4).

Table 3. Occupancy estimates (ψ) and standard errors (SE) across four seasons for elk, deer, lion, bear, coyote, bobcat, and fox (December 2017- November 2018).

Species	Season	Ψ	SE
Elk	Spring	0.680	0.111
	Summer	0.610	0.070
	Fall	0.585	0.075
	Winter	0.576	0.081
Deer	Spring	0.807	0.091
	Summer	0.781	0.084
	Fall	0.768	0.097
	Winter	0.762	0.108
Lion	Spring	0.364	0.316
	Summer	0.445	0.293
	Fall	0.516	0.297
	Winter	0.578	0.298
Bear	Spring	0.495	0.265
	Summer	0.289	0.166
	Fall	0.192	0.190
	Winter	0.147	0.184
Coyote	Spring	0.163	0.159
	Summer	0.290	0.097
	Fall	0.375	0.125
	Winter	0.431	0.165
Bobcat	Spring	0.587	0.259
	Summer	0.569	0.204
	Fall	0.552	0.187
	Winter	0.535	0.224

	Spring	0.399	0.329
	Summer	0.372	0.252
Fox	Fall	0.347	0.229
	Winter	0.324	0.230

Table 4. Estimated average occupancy (ψ) with 95% confidence intervals across all seasons for elk, deer, fox, and lion (December 2017 - November 2018).

Species	Occupancy (ψ)
Elk	0.68 (0.43 – 0.85)
Deer	0.81 (0.57 – 0.93)
Lion	0.36 (0.01 – 0.96)
Bear	0.50 (0.15 – 0.84)
Coyote	0.16 (0.05 – 0.41)
Bobcat	0.40 (0.11 – 0.23)
Fox	0.40 (0.11 – 0.78)
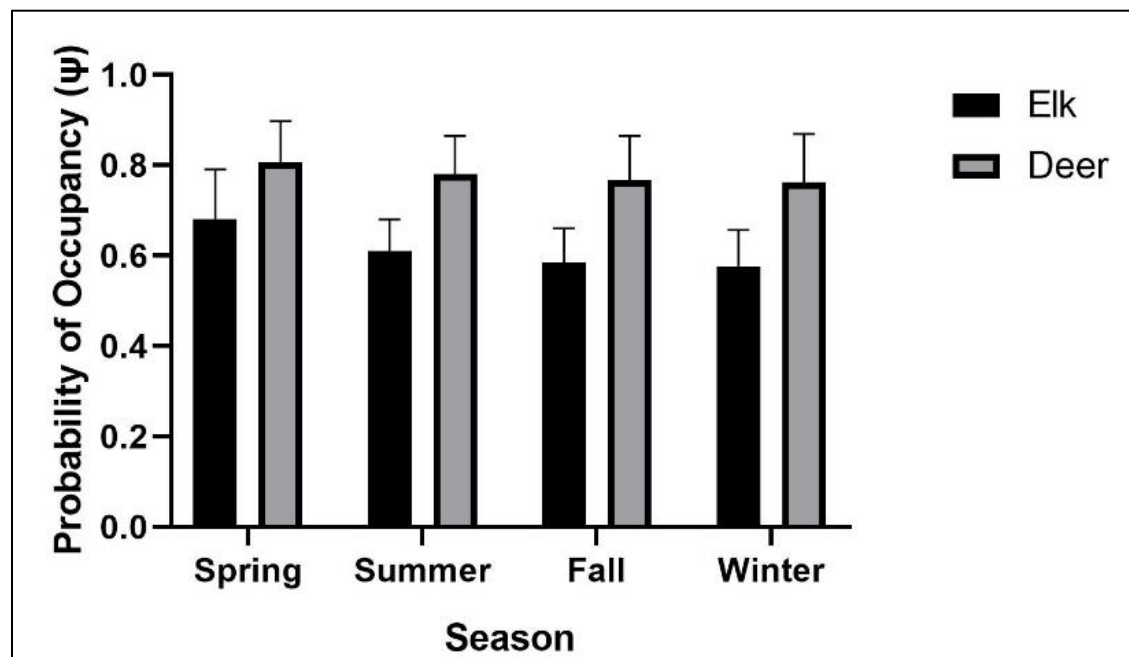
Figure 2. Probability of occupancy and standard error by season for elk and deer at LANL (December 2017 - November 2018).
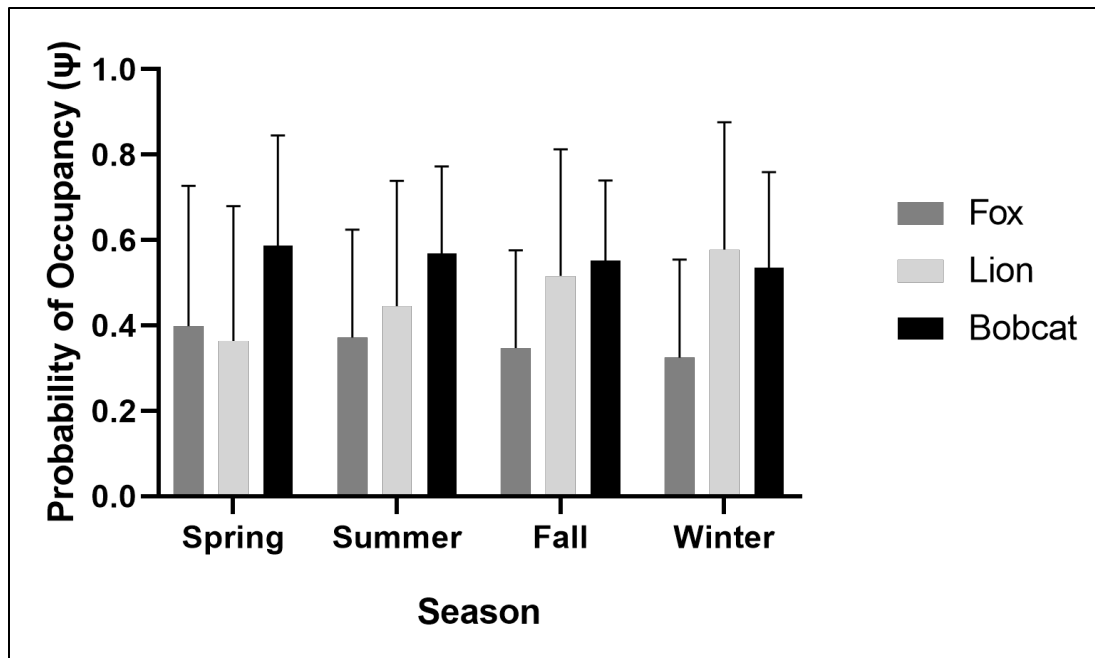
Figure 3. Probability of occupancy and standard errors by season for fox, lion, and bobcat at LANL (December 2017 - November 2018).
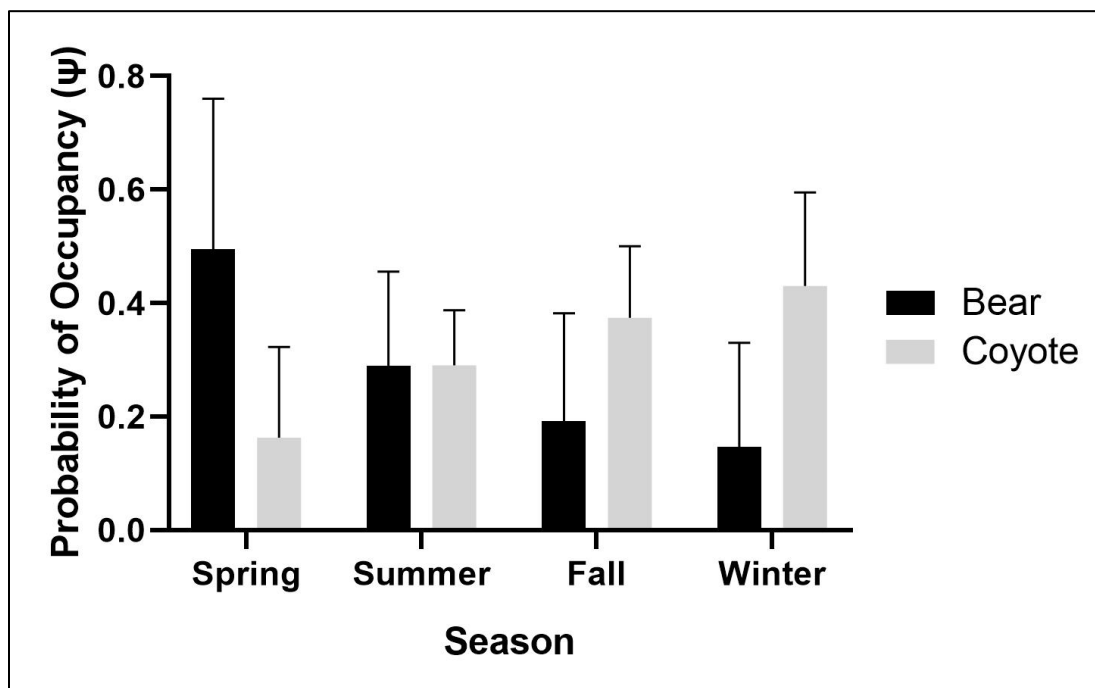
Figure 4. Probability of occupancy (ψ) and standard errors by season for bear and coyote at LANL (December 2017 - November 2018).

Detection Probability
With seasons combined, detection probability was highest for deer at 0.315 and lowest for lion at 0.018 (Table 5). This indicates that there is a 32% probability to detect deer at a given site across all seasons; whereas there is only a 1.8% probability to detect a lion. The top model for deer, elk, lion, and fox showed constant detection probabilities through all seasons and are therefore given as the average detection probability across all seasons (Table 5); whereas the top model for bear, coyote, and bobcat showed varying detection probabilities through all seasons (Table 6; Figure 5). For example, during the fall there is a 21% probability to detect a coyote at a given site while during the winter there is a much lower probability of 3.7%.

Table 5. Estimated average probability of detection (p) ± standard error (SE) across all seasons for elk, deer, fox, and lion (December 2017 - November 2018).

Species	Detection Probability (p) ± SE
Elk	0.216 ± 0.018
Deer	0.315 ± 0.017
Fox	0.022 ± 0.013
Lion	0.018 ± 0.010

Table 6. Probability of detection (p) by season for bear, coyote, and bobcat (December 2017 - November 2018).

Species	Spring	Summer	Fall	Winter
Bear	0.097	0.039	0.167	0.000
Coyote	0.120	0.188	0.211	0.037
Bobcat	0.033	0.027	0.077	0.021

Occupancy combined with Detection Probability
We plotted occupancy by detection probability (Figures 6 and 7) to group species as common or rare according to their occupancy and detectability (Shannon et al. 2014). There were no differences in detection probability by season for lion, fox, deer, and elk, therefore they are all included in Figure 6. For our study, lion and fox showed moderate occupancy with overall low detection probability, while deer and elk showed high occupancy and high detection probability through all four seasons (Figure 6).
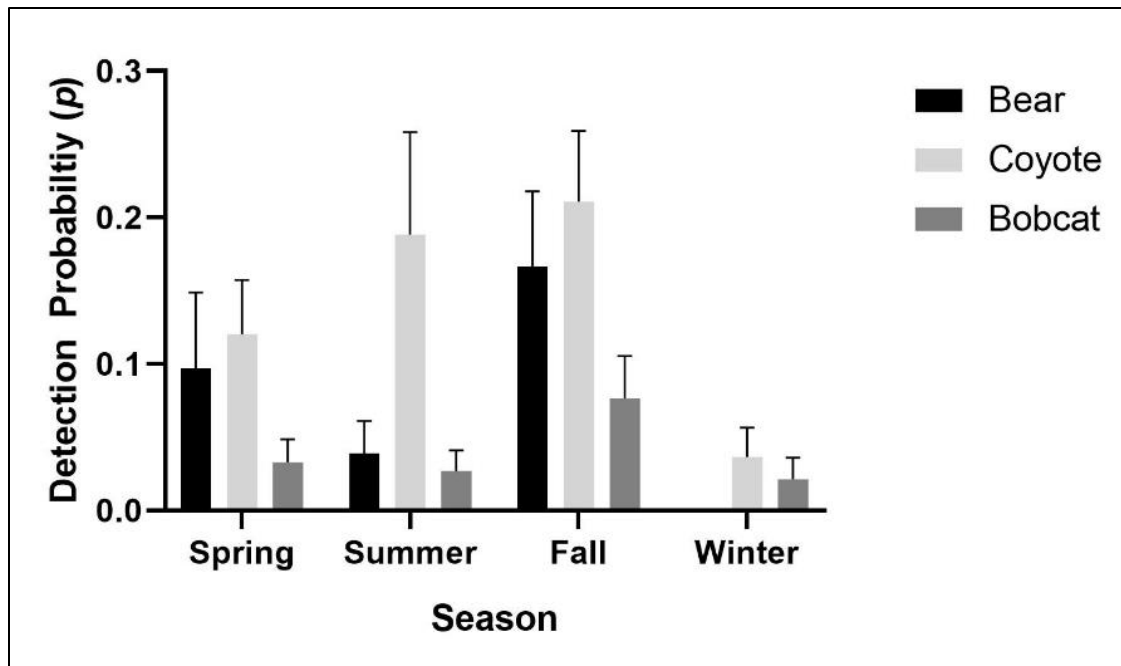
Figure 5. Detection probability (p) and standard errors by season for those species that were shown to have differences in detection probabilities by season at LANL (December 2017 - November 2018).
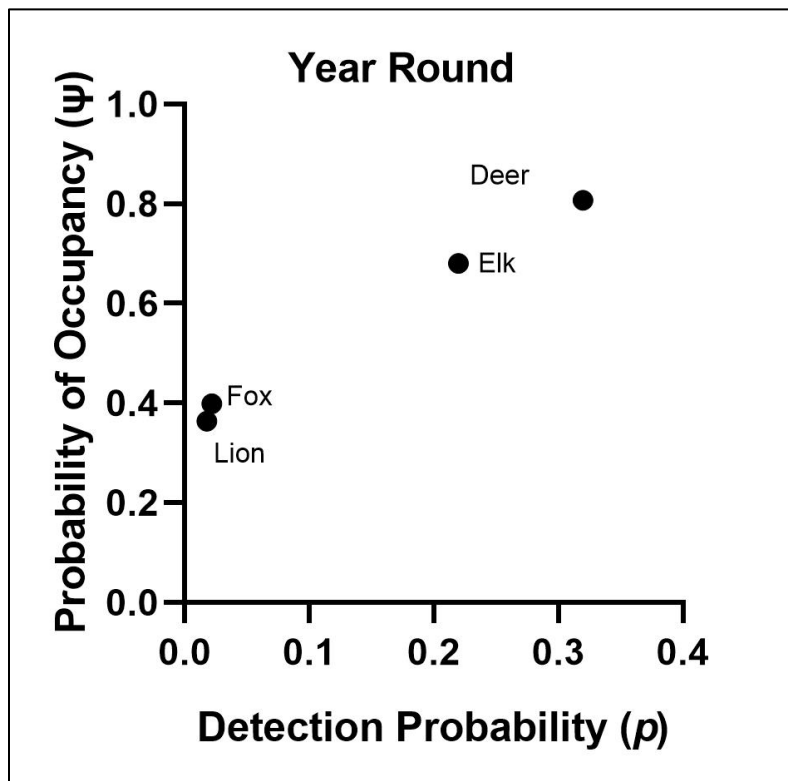
Figure 6. Probability of occupancy (ψ) and detection (p) at a given site across all seasons conditional on presence of an animal at that site for elk, deer, lion, and fox at LANL (December 2017 - November 2018).

Bear, coyote, and bobcat showed seasonal variation in occupancy and/or detection probabilities, and therefore are displayed by season in Figure 7. The probability of bobcat occupancy at a sampled location is highest in the spring, fall, and winter, but they have a higher detection probability in the summer when their occupancy is the lowest. Coyotes have a low probability of occupancy at a sampled location in the spring and summer, and a higher probability of occupancy in the fall and winter. Bears have a higher probability of occupancy at a sampled location in the spring, but have a greater chance of being detected during the fall and are least likely to be detected during the winter.
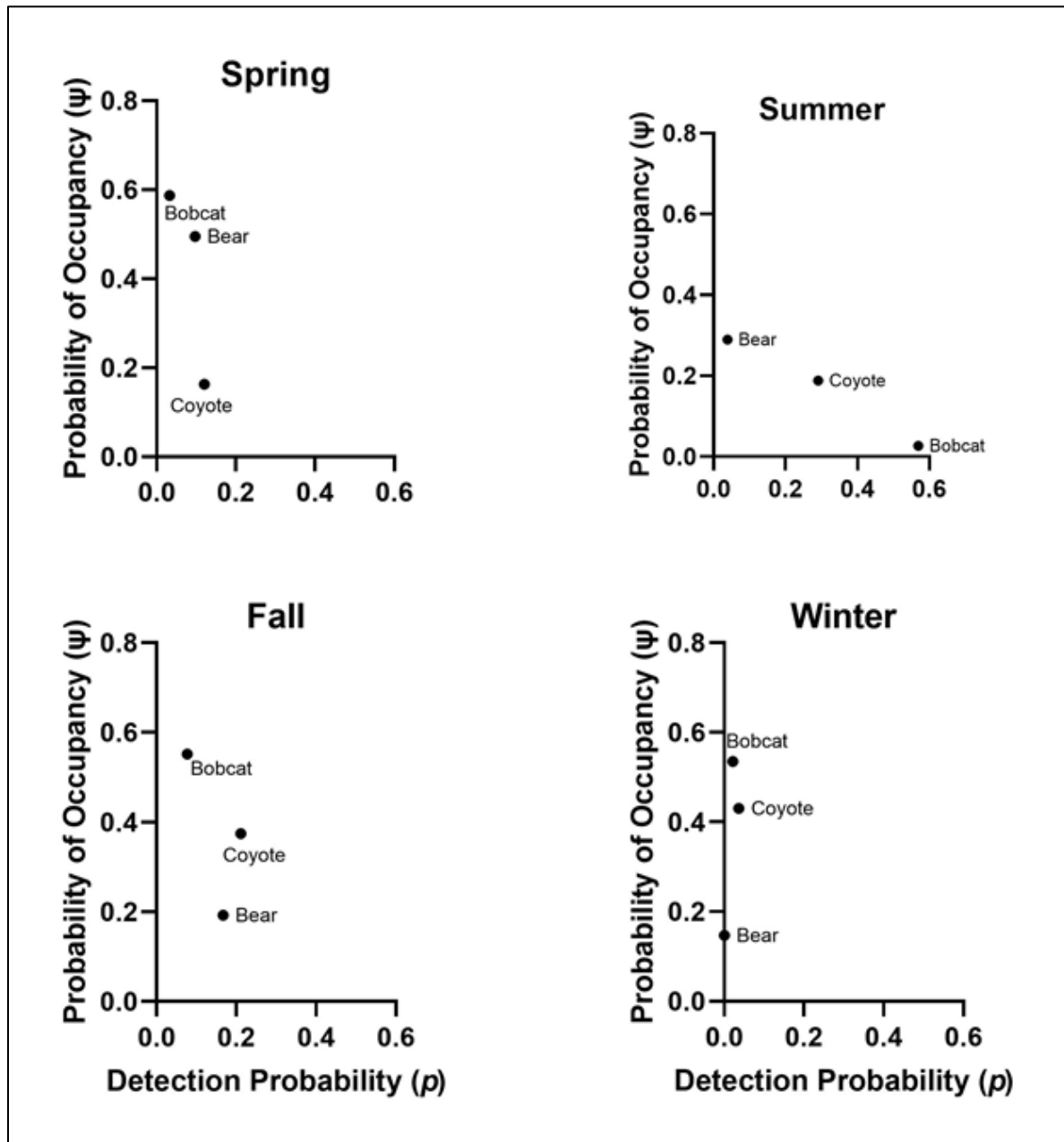
Figure 7. Probability of occupancy (ψ) and detection (p) by season at a given site, conditional on presence of an animal at that site for bobcat, coyote, and bear at LANL (December 2017 - November 2018).

Discussion

One of the basic tenants of ecology (Odum 1983) is the assumption that energy is transferred through various trophic levels, i.e. producers > primary consumers (herbivores) > secondary consumers (carnivores). Following this logic there will be less energy available at each successive trophic level, and therefore at the highest level (carnivores) there will be less available energy to support fewer individuals. Furthermore, it makes sense that our highest detection probabilities and occupancy rates came from primary consumers (elk and deer), while the reverse was true for secondary consumers (lion, fox, bobcat, etc.). Under this pretext, further potential explanations for why occupancy and detection rates vary across species is described below.

The most common animals accounted for during our study were deer and elk. Deer had an average 81% occupancy rate and elk had a 68% occupancy rate across all seasons. These data indicate that both deer and elk have a high probability of occupancy on LANL property year round. It was not possible to identify specific individuals since there were no marked individuals. However, it is possible to suggest that deer and elk on LANL property are potentially non-migratory (off and on site) in their behavior. This could be a result of the limited access of the property as a whole and the exclusion of human hunting pressure. Another possible explanation may be the existence of all necessary habitat components for both species within LANL property and there being no need to engage in any migration off site. A study conducted on site in the late 1990's utilizing GPS collared individuals found that the majority of elk monitored had home ranges that were primarily on LANL property and Pueblo de San Ildefonso Indian Reservation land and displayed a strong preference for pinion/juniper and ponderosa pine (*Pinus ponderosa*) habitats (Biggs et al. 1999). This coincides with our results, where elk were documented across the property and in all seasons. The number of detections by season and location were mapped to display these data (Figure 8). Maps for each species are shown in Appendix A.

The results of occupancy and detection probabilities for deer, lions, and foxes in our study were similar to results documented in a study performed in the southern Rocky Mountains in Colorado (Shannon et al. 2014), although they did not incorporate seasonal variation into their models. Animals with high detection and occupancy probability, in our case deer and elk, may result in a higher ability to detect a population change during future surveys (Steenweg et al. 2019).

Lion and fox showed intermediate levels of occupancy with overall low detection probabilities. The results suggest that these species are both elusive and difficult to detect, but they are both known to occur on LANL property year round despite having much smaller population sizes. Given the size differences between these two species, a small chance for direct competition for resources exists and the fox could become an opportunistic prey item for an apex predator like the lion. Koehler and Hornocker (1991) documented food habit and resource use overlap in winter months resulting in predation on coyote and bobcat by mountain lions. It is likely that lions could opportunistically prey on foxes just as easily.
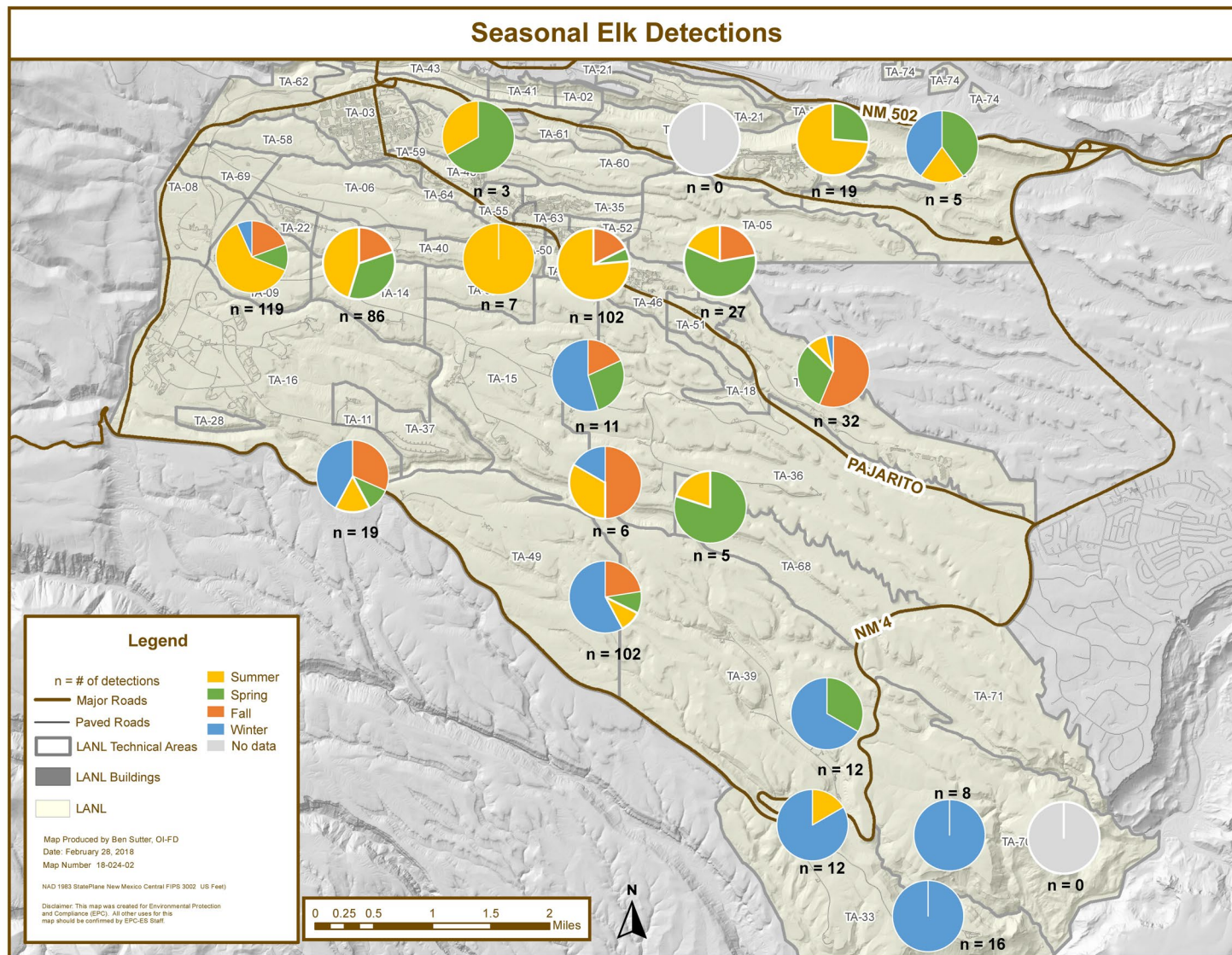
Figure 8. Seasonal elk detections by site.

Lion occupancy may also be less prominent onsite because of anthropogenic development and activity, which in turn may have a positive "release" effect on some mesopredator communities as documented in other studies (Wang et al. 2015). Conversely, lions and foxes have a low detection probability which could be improved using complimentary survey techniques or increasing the number of camera trap sites and the number of survey days (Shannon et al. 2014, Steenweg et al. 2019).

At sample locations, the occupancy of bear, coyote, and bobcat varied by season. The results suggest that coyotes have a high probability of occupancy during the winter which may be due to their breeding season occurring from January to February. Bobcats have a more consistent occupancy rate throughout seasons. Searching for mates could have affected their occupancy rates during winter but this factor could have been a generalized need to locate food during a time of year when resources are constrained (Anderson and Lovallo 2003). The detection probability for the coyote was higher than bear and bobcat across all seasons, which may be due to higher fecundity rates. For example, coyotes have three to seven pups per litter (Carlson 2008), bobcats have three kittens per litter (Anderson Lovallo 2003), and bears have one to three cubs per litter every other year (Costello et al. 2001). With more individuals entering the landscape every year, it can therefore be assumed that species will have larger populations. From a behavioral aspect, coyotes display social monogamy in packs that are formed with alpha males and females breeding and older offspring staying to act as "helpers" (Bekoff and Gese 2003). This is evident from detections in which a series of photos showed multiple adults and juveniles in groups. Alternatively, no documented detections of adult bears or bobcats with their young or series of detections, showed more than one adult. From a diet perspective, the coyote is benefited by being a more generalist mesopredator that can utilize a variety of foods. Bears reflect this general strategy as omnivores, but they are a classic "k-selected" species in that there is considerable time and energy required to reach reproductive status (Carlson 2008, Costello et al. 2001). It takes bears three years to reach sexual maturity, but only 10 months for coyotes (Carlson 2008).

Bears displayed a low occupancy rate during winter most likely due to hibernation. However, in the spring the occupancy of bears increases. This is likely because both male and female bears display expanded movement patterns to account for a post hibernation need for food (Lariviere 2001). In the fall, bears, especially males, are more likely to be detected because they are moving large distances to find seasonal food sources to increase their fat storage for the winter (Costello 2010). During this time, females are also trying to increase fat stores but have been shown to have a high degree of philopatry and do not tend to move far from their natal range (Costello 2010). Additional research on distribution and sex ratios is needed to determine if these same phenomena occur on LANL property.

Management implications

From the results, it is apparent that there is a great degree of variation between detectability and occupancy of the seven species analyzed, both seasonally and annually. Seasonal variation in occupancy is important to understand on a landscape that is active with federal management

projects and has a high level of biodiversity. Obtaining occupancy and abundance data for common species on LANL property may help inform management about mitigating and managing human-wildlife interactions.

Vehicle-animal collisions are common at LANL. While there have been studies documenting accidents and pinch points along animal migration and human travel corridors (Biggs et al. 2004, Bennett et al. 2014), vehicle strikes still occur. Lighted signs have been installed along travel routes, but there is no formal tracking of the exact numbers of collisions that occur on LANL property annually. Therefore, a continual and replicable monitoring program that aids in identifying trends and changes over time would be worthwhile. With the continued development across LANL property to meet mission objectives, it is crucial to understand how human activities impact wildlife resources. Maintaining existing migration corridors by delineating and preserving green space around a corridor is strongly recommended.

Encounters with bears at dumpsters are another common human-wildlife interaction at LANL. This research is useful to determine the timing of increased bear occupancy at sampled locations. Managers can be better informed of increased bear activity and ensure bear resistant dumpsters are functional during those times. Data presented in this study demonstrate quantitatively that bears have higher occupancy on LANL property during the spring and summer seasons.

Future Research

This study has yielded results that form a general understanding of occupancy of seven wildlife species across LANL property over one year. Constant or periodic monitoring is required to better refine the models developed here.

Additionally, further analyses of the seven species discussed in this study using camera traps modeled with variables such as land cover, elevation, distance to development, distance to water, and climate would increase the body of knowledge of wildlife occupancy on LANL property. Modeling wildlife occupancy in relation to human development to identify areas used by and important to wildlife. Performing a replication of earlier studies such as Muldavin and Yanoff (1999), and coupling data from this and previous studies such as Biggs et al. (1999) would identify trends over time in wildlife usage in relation to onsite development. This knowledge could better inform management decisions to steer new developments into areas that are not as valuable to wildlife or to encourage the use of areas that are already developed.

The majority of mesocarnivores identified on LANL property include gray fox, coyote, and bobcat. Only one detection of an American Hog-nosed Skunk (*Conepatus leuconotus*) was made and only two detections of raccoon (*Procyon lotor*) were made. A targeted occupancy study for smaller mesocarnivores, like raccoons and skunks, would help in addressing gaps in knowledge of community composition on LANL property.

Acknowledgements

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Appendix A – Maps of detections by site, season, and species
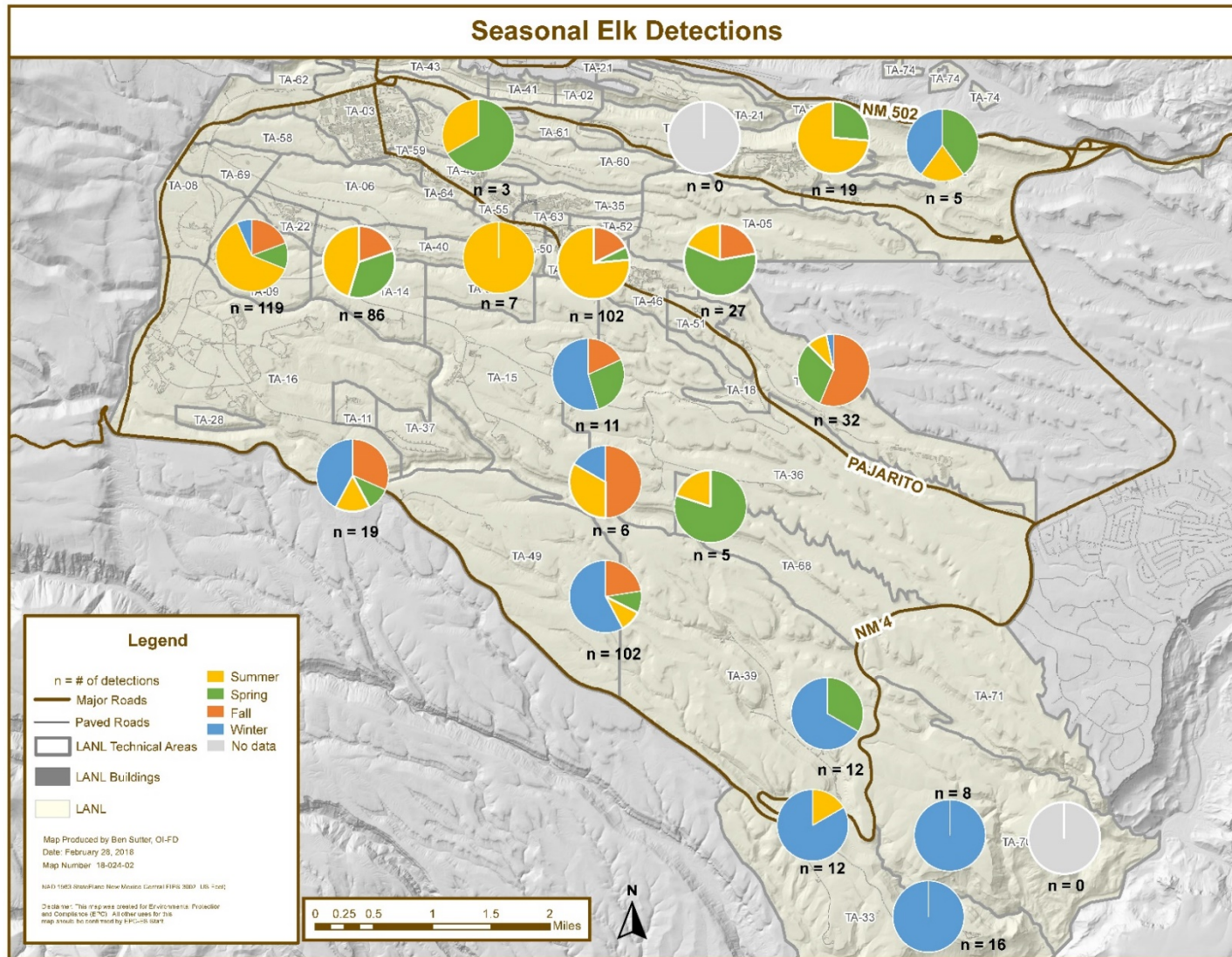
Figure A1. Seasonal elk detections across LANL property based on photo data.
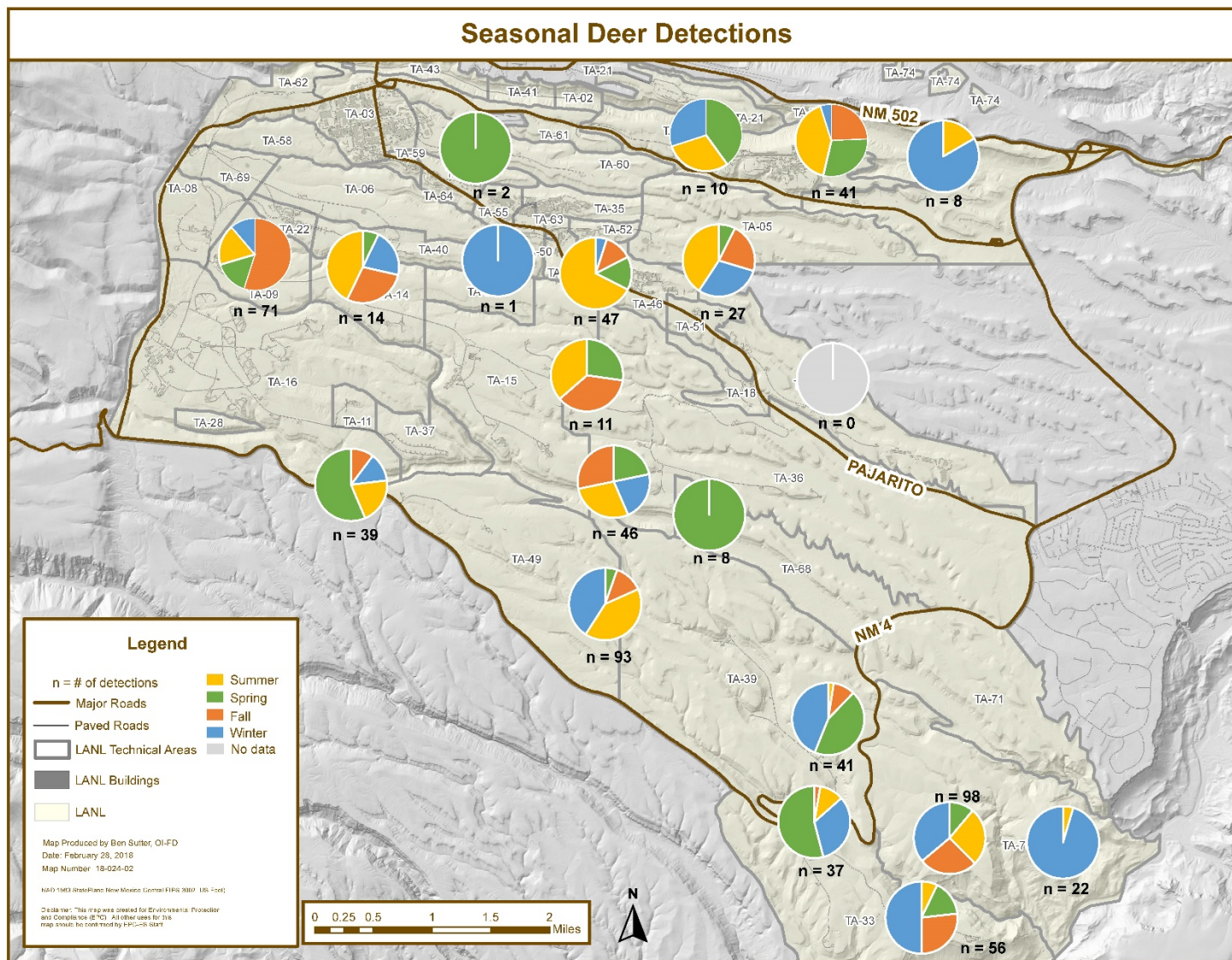
Figure A2. Seasonal deer detections across LANL property based on photo data.
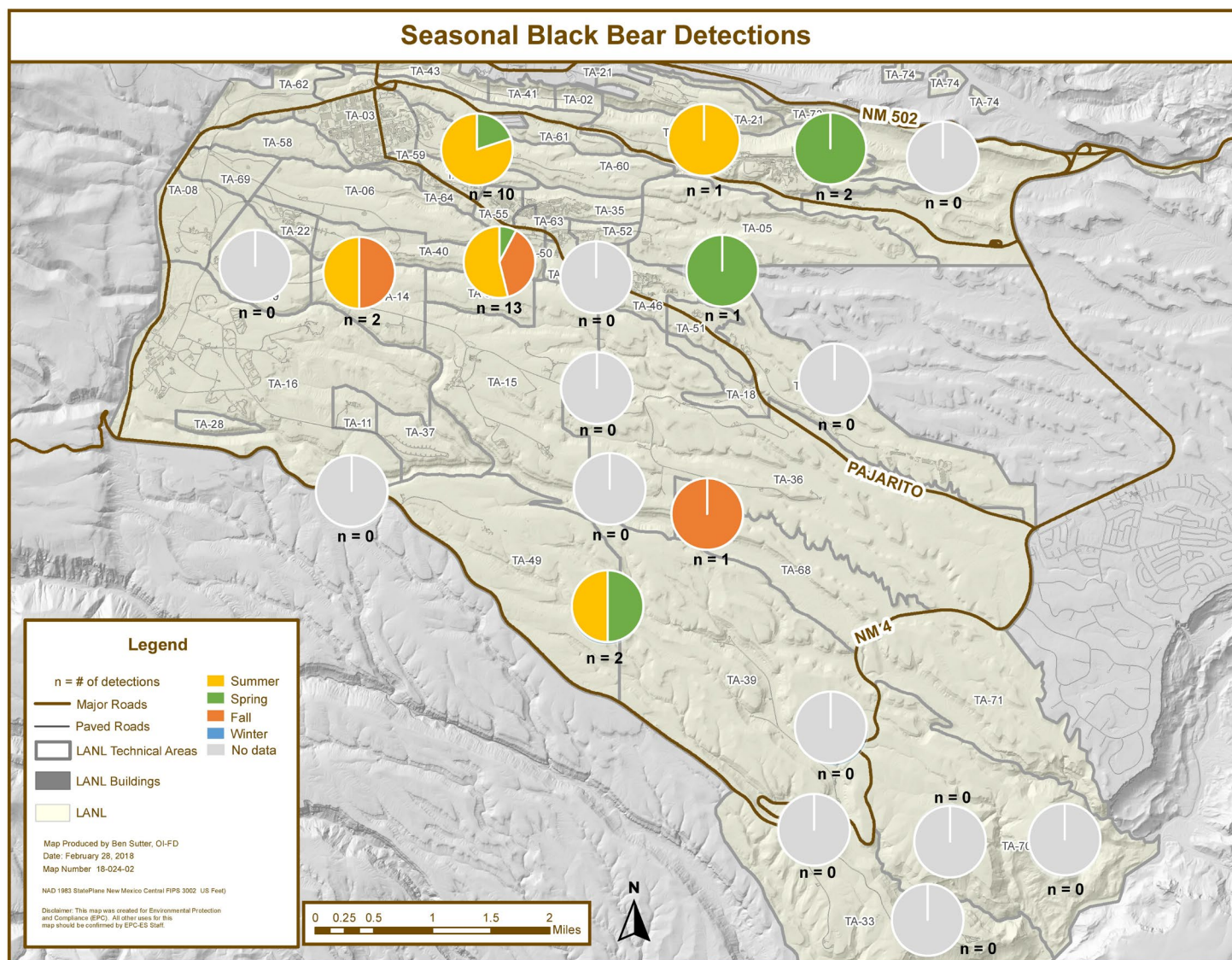
Figure A3. Seasonal bear detections across LANL property based on photo data.
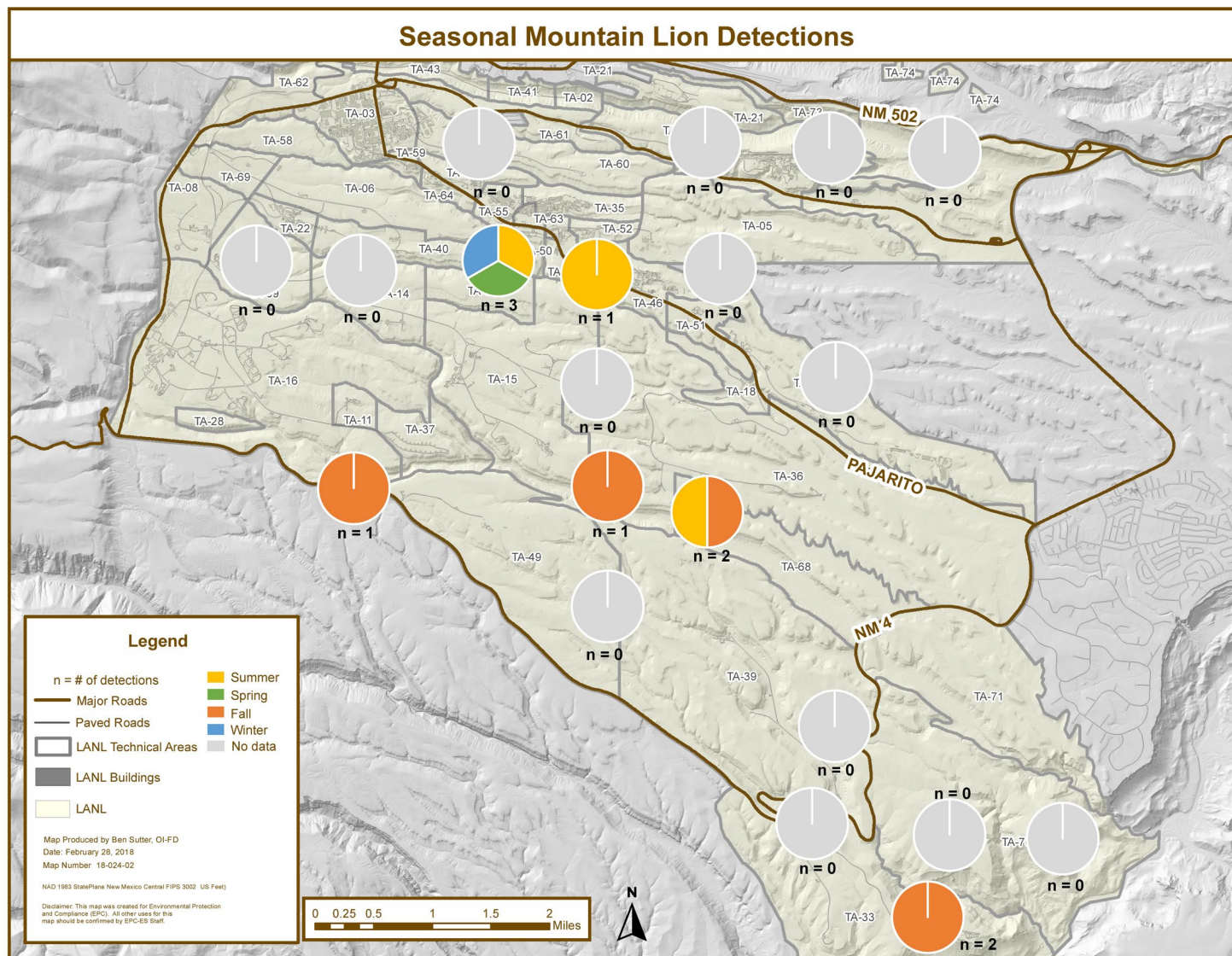
Figure A4. Seasonal lion detections across LANL property based on photo data.
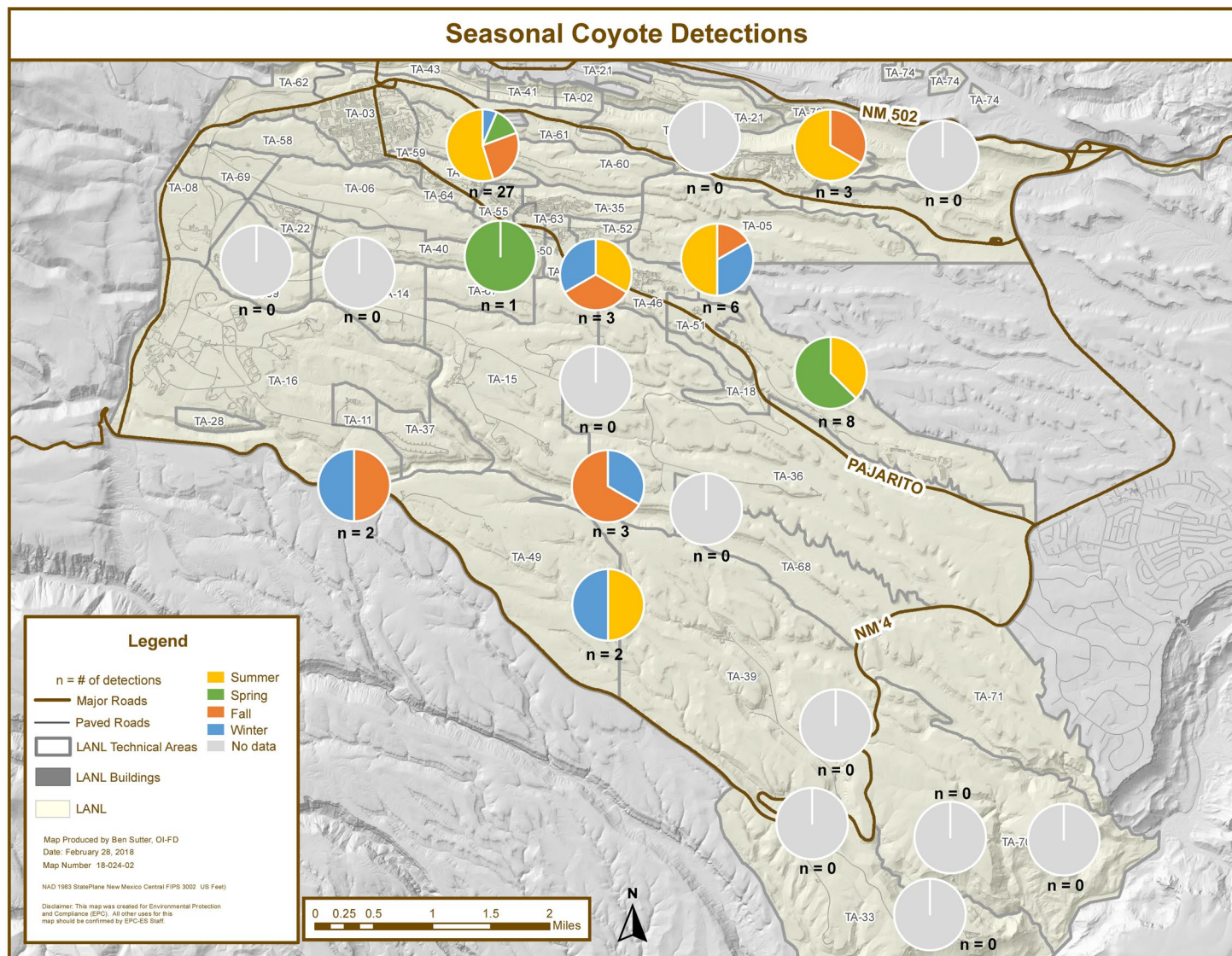
Figure A5. Seasonal coyote detections across LANL property based on photo data.
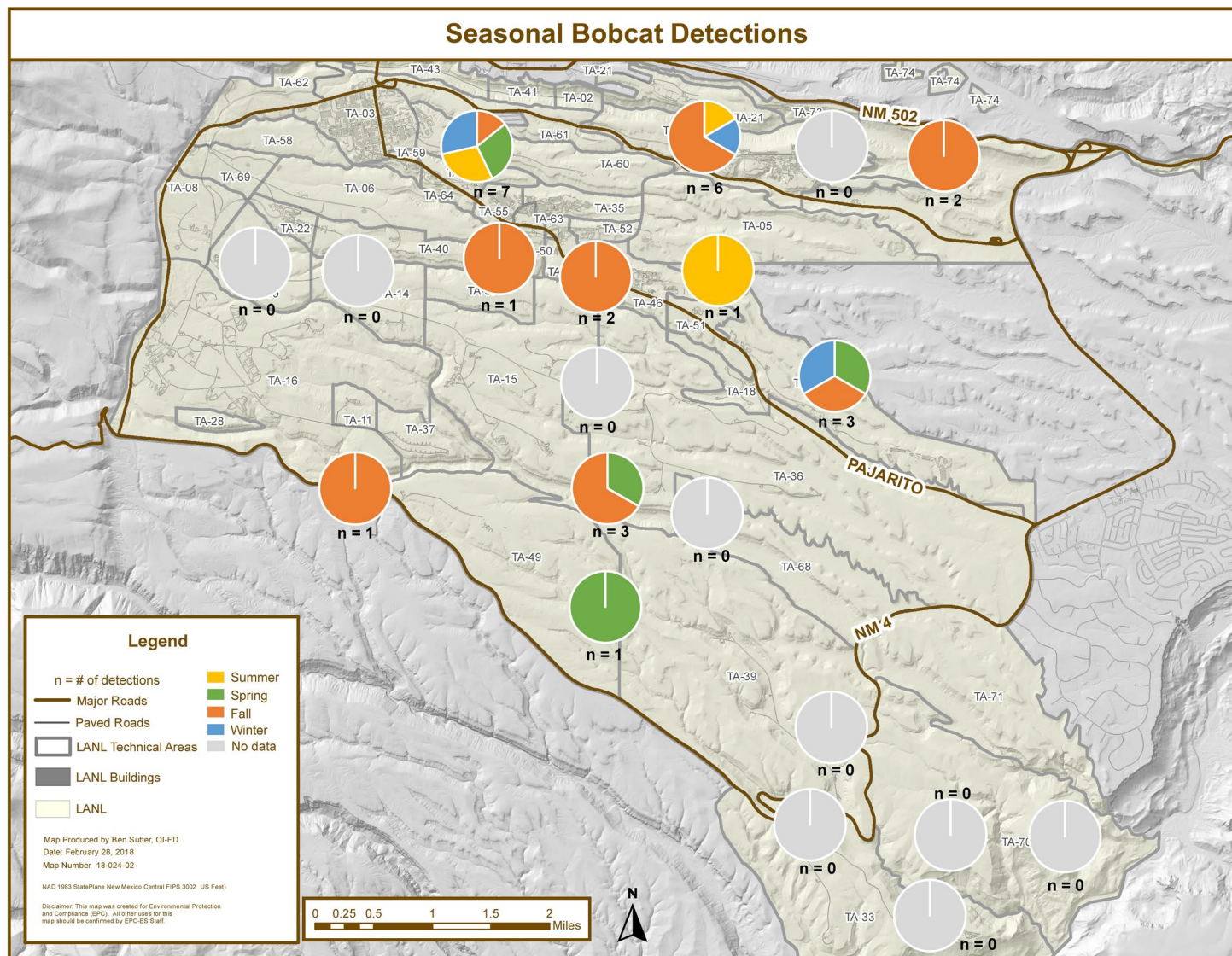
Figure A6. Seasonal bobcat detections on LANL property based on photo data.
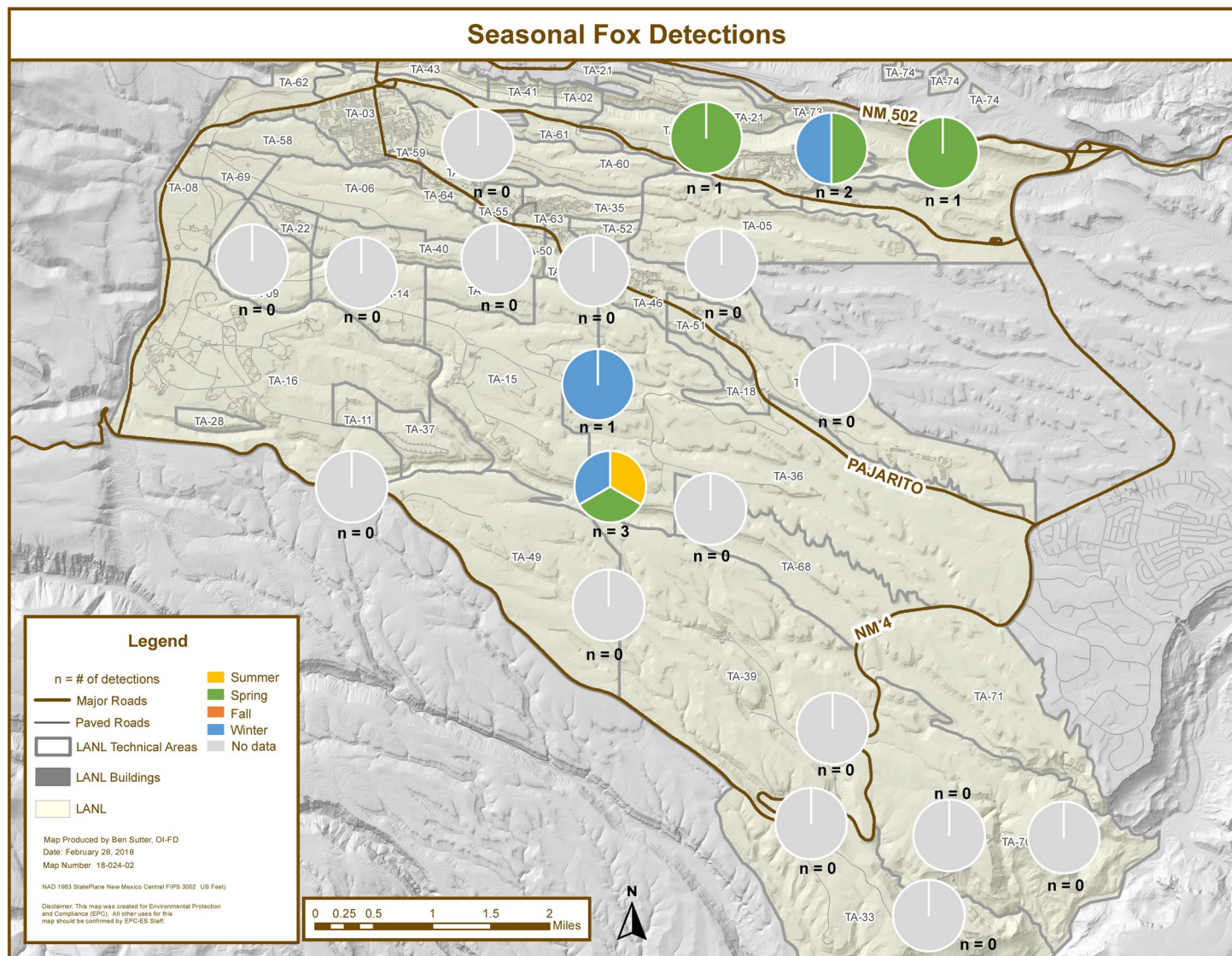
Figure A7. Seasonal fox detections across LANL property based on photo data.

Appendix B – Summary tables of all data

Table B1. Total detections per camera during fall, categorized by species. In this study, September through November included fall detections.

					Fall						
Camera	Abert's Squirrel *(Scuirus aberti)*	Bear	Bobcat	Chipmunk	Coyote	Deer	Elk	Lion	Raccoon	Unknown	Total
3	2	0	1	0	8	0	0	0	2	0	13
5	0	0	4	0	0	0	0	0	0	0	4
6	1	0	0	0	1	10	0	0	0	0	12
7	0	0	2	0	0	0	0	0	0	0	2
8	0	0	0	0	0	39	23	0	0	0	62
9	0	1	0	0	0	4	17	0	0	0	22
10	0	5	1	0	0	0	0	0	0	0	6
11	0	0	2	1	1	7	18	0	0	3	32
12	0	0	0	0	1	6	6	0	0	1	14
19	0	0	0	0	0	4	2	0	0	0	6
21	0	0	1	0	0	0	18	0	0	0	19
22	0	0	1	0	1	4	6	1	0	0	13
24	0	0	2	0	2	13	3	1	0	0	21
25	0	1	0	0	0	0	0	1	0	0	2
28	0	0	0	0	0	12	23	0	0	0	35
33	0	0	0	0	0	4	0	0	0	0	4
35	0	0	0	0	0	1	0	0	0	0	1
36	0	0	0	0	0	26	0	0	0	0	26
37	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	0	15	0	2	0	0	17
Total	**3**	**7**	**14**	**1**	**14**	**145**	**116**	**5**	**2**	**4**	**311**

Table B2. Total detections per camera during spring, categorized by species. In this study, March through May included spring detections.

						Spring					
Camera	**Bear**	**Bird** *(Aphelocoma woodhouseii)*	**Bobcat**	**Coyote**	**Deer**	**Elk**	**Lion**	**Rabbit**	**Raccoon**	**Unknown**	**Total**
3	2	0	2	4	2	2	0	0	2	0	14
5	0	0	0	0	4	0	0	0	0	0	4
6	2	0	0	0	12	5	0	0	0	0	19
7	0	0	0	0	0	2	0	0	0	0	2
8	0	0	0	0	11	14	0	0	0	1	26
9	0	0	0	0	1	30	0	0	0	1	32
10	1	0	0	1	0	0	1	0	0	0	3
11	0	0	0	0	6	6	0	0	0	0	12
12	1	1	0	0	2	16	0	1	0	2	23
19	0	0	0	0	3	3	0	0	0	0	6
21	0	1	1	5	0	10	0	1	0	1	19
22	0	0	0	0	22	2	0	0	0	0	24
24	0	0	1	0	10	0	0	0	0	0	11
25	0	0	0	0	8	4	0	0	0	0	12
28	1	0	1	0	5	10	0	0	0	0	17
33	0	0	0	0	18	4	0	0	0	0	22
35	0	0	0	0	20	0	0	0	0	0	20
36	0	0	0	0	10	0	0	0	0	0	10
37	0	0	0	0	0	0	0	0	0	0	0
39	0	0	0	0	9	0	0	0	0	0	9
Total	7	2	5	10	143	108	1	2	2	5	285

Table B3. Total detections per camera during summer. In this study, June through August included summer detections.

Camera	Abert's Squirrel	Bear	Bird (Tyrannidae)	Bobcat	Coyote	Deer	Elk	Insect	Lion	Unknown	Total
3	2	8	0	2	17	0	1	0	0	0	30
5	0	1	0	1	0	3	0	0	0	0	5
6	0	0	0	0	2	17	14	0	0	0	33
7	0	0	0	0	0	1	1	0	0	0	2
8	0	0	0	0	0	13	74	0	0	0	87
9	0	1	0	0	0	6	39	0	0	1	47
10	0	7	0	0	0	0	7	0	1	0	15
11	0	0	0	0	1	31	78	0	1	5	116
12	0	0	0	1	3	11	5	0	0	0	20
19	0	0	0	0	0	4	0	0	0	0	4
21	0	0	3	0	3	0	3	0	0	1	10
22	0	0	0	0	0	8	3	1	0	0	12
24	0	0	0	0	0	13	2	0	0	1	16
25	0	0	0	0	0	0	1	0	1	0	2
28	0	1	0	0	1	38	10	0	0	2	52
33	0	0	0	0	0	1	0	0	0	0	1
35	0	0	0	0	0	4	2	0	0	1	7
36	0	0	0	0	0	23	0	0	0	0	23
37	0	0	0	0	0	1	0	0	0	0	1
39	0	0	0	0	0	4	0	0	0	0	4
Total	2	18	3	4	27	178	240	1	3	11	487

Table B4. Total detections per camera during winter. In this study, December through February included winter detections.

Camera	Bobcat	Coyote	Deer	Elk	Lion	Rabbit	Unknown	Total
			Winter					
3	2	2	0	0	0	0	0	4
5	1	0	3	0	0	0	0	4
6	0	0	2	0	0	0	0	2
7	0	0	7	2	0	0	0	9
8	0	0	8	8	0	0	0	16
9	0	0	3	0	0	0	0	3
10	0	0	1	0	1	0	1	3
11	0	1	3	0	0	0	0	4
12	0	1	8	0	0	1	0	10
19	0	0	0	6	0	0	0	6
21	1	0	0	1	0	1	0	3
22	0	0	5	8	0	0	0	13
24	0	0	10	1	0	0	0	11
25	0	0	0	0	0	0	0	0
28	0	1	38	59	0	0	0	98
33	0	0	18	8	0	0	0	26
35	0	0	12	10	0	0	0	22
36	0	0	39	8	0	0	0	47
37	0	0	21	0	0	0	0	21
39	0	0	28	16	0	0	1	45
Total	**4**	**5**	**206**	**127**	**1**	**2**	**2**	**347**

Appendix C – Representative pictures of wildlife

Figure C1. Cow elk and her calf captured at camera 12 on 6 June 2018 at 3:10 P.M.

Figure C2. Bull elk captured at camera 28 on 30 December 30 2018 at 3:22 P.M.
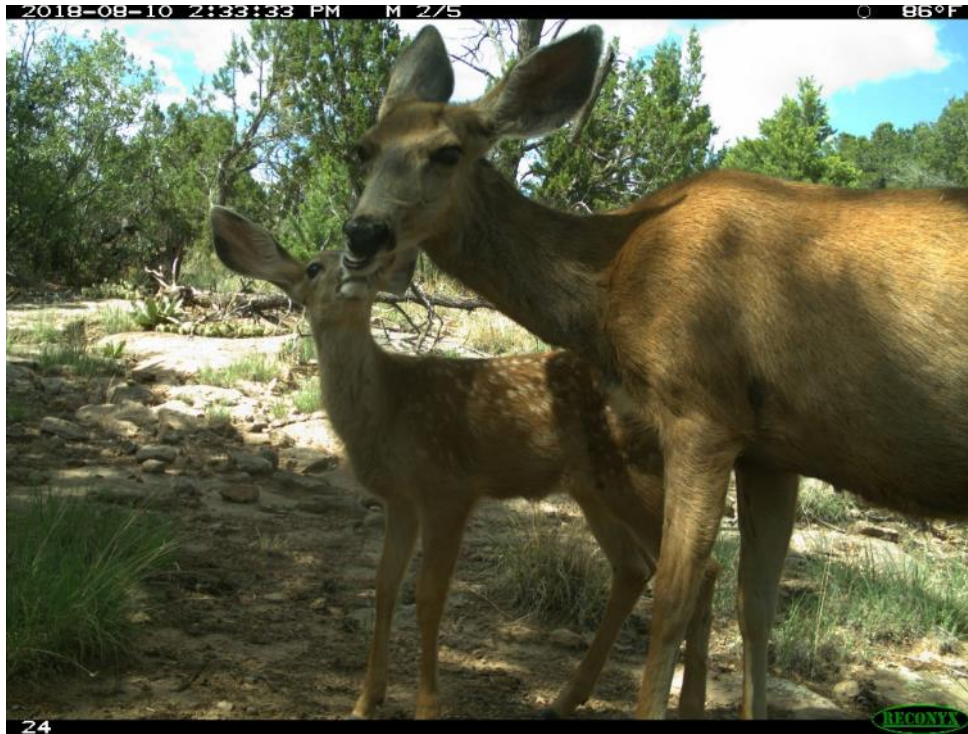
Figure C3. Deer doe and fawn captured at camera 24 on 10 August 2018 at 2:33 P.M.

Figure C4. Deer buck captured at camera 39 on 28 December 2019 at 5:17 P.M.

Figure C5. Bear captured at camera 10 on 15 September 2018 at 12:44 P.M.

Figure C6. Mountain lion captured at camera 37 on 19 February 2019 at 8:28 A.M.
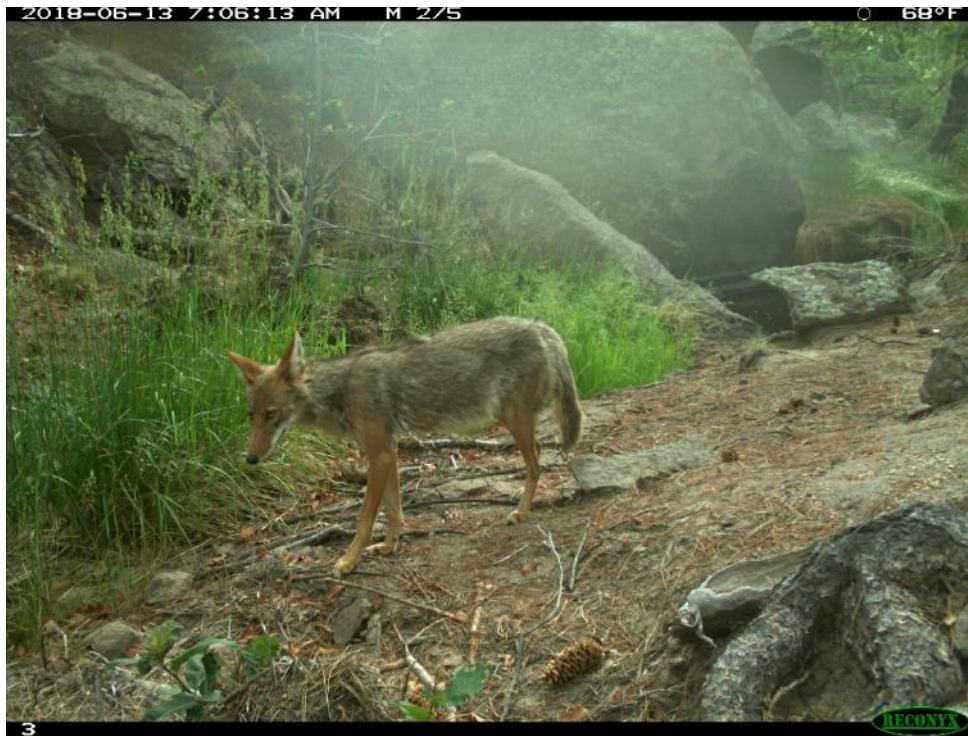
Figure C7. Coyote captured at camera 3 on 13 June 2018 at 7:06 A.M.

Figure C8. Coyote captured at camera 6 on 25 January 2018 at 10:55 P.M.

Figure C9. Bobcat captured at camera 3 on 21 February 2018 at 4:18 P.M.

Figure C10. Gray fox captured at camera 7 on 21 April 2018 at 2:46 P.M.

Figure C11. Raccoon captured at camera 3 on 14 September 2018 at 1:52 A.M.

Figure C12. Abert's squirrel captured at camera 3 on 27 August 2018 at 11:08 A.M.

Figure C13. Coyote adults and pups captured at camera 21 on 26 June 2018 at 5:51 A.M.

Figure C14. Bull elk asleep in front of camera 36 through the night of 16 January 2019. Photo captured at 10:26 P.M.

Appendix D – Camera data

Table D1. Location and setup data for each camera used in this study.

Camera	Date Deployed	1st check	2nd check	Date Pulled	Orientation	Degree	Latitude	Longitude	Elevation (feet)	Attached to
3	11/21/17	2/26/18	9/6/18	2/5/19	NNE	23	35.87207	-106.30605	7188	PSME (live)
5	11/21/17	2/23/18	9/7/18	2/5/19	WNW	307	35.87314	-106.27128	6701	PIPO (live)
6	11/21/17	2/23/18	9/7/18	2/5/19	SSW	210	35.87267	-106.25259	6578	JUMO (live)
7	11/21/17	2/23/18	9/7/18	2/5/19	ENE	70	35.87074	-106.23534	6513	JUMO (live)
8	1/31/18	5/17/18	10/3/18	2/5/19	N	10	35.85754	-106.34043	7529	PIPO (live)
9	1/31/18	5/18/18	10/3/18	3/8/19	NW	342	35.85621	-106.32419	7290	PIPO (live)
10	1/30/18	2/27/18	10/17/18	2/27/19	SE	126	35.85813	-106.30255	7077	PSME (live)
11	11/21/17	2/26/18	9/6/18	2/5/19	N	31	35.85634	-106.28896	7090	PIPO (live)
12	11/20/17	2/26/18	10/17/18	2/5/19	NNE	30	35.85719	-106.26977	7001	JUMO (live)
19	1/29/18	3/7/18	10/5/18	2/7/19	NE	64	35.84270	-106.28947	6929	JUMO (live)
21	11/20/17	2/26/18	9/6/18	2/5/19	NNE	33	35.84307	-106.25209	6713	JUMO (live)
22	2/1/18	4/20/18	9/18/18	2/7/19	N	359	35.82882	-106.32490	7230	PIPO (live)
24	1/29/18	4/26/18	10/5/18	3/6/19	NNW	349	35.82939	-106.28651	6961	PIED (live)
25	1/29/18	4/26/18	10/5/18	3/6/19	NNW	350	35.82630	-106.27094	6745	PIED (live)
28	11/30/17	3/23/18	9/18/18	3/8/19	NNE	24	35.81498	-106.28675	6820	PIPO (live)
33	2/1/18	4/20/18	9/18/18	2/4/19	NE	19	35.79953	-106.25299	6522	JUMO (live)
35	12/21/17	3/1/18	9/13/18	2/6/19	S	166	35.78780	-106.25537	6259	PIPO (live)
36	1/22/18	3/1/18	10/17/18	2/6/19	NE	40	35.78542	-106.23446	6432	PIED (live)
37	1/18/18	3/1/18	10/17/18	2/27/19	NE	56	35.78534	-106.21684	6240	JUMO (live)
39	12/21/17	3/1/18	9/13/18	2/6/19	NNW	326	35.77238	-106.23674	6427	JUMO (live)

Note: PSME is the species code for Douglas fir (*Psuedotsuga menziesii*); PIPO is ponderosa pine (*Pinus ponderosa*); JUMO is oneseed juniper (*Juniperus monosperma*); PIED is pinyon pine (*Pinus edulis*).